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Thesis/Dissertation

Short Term Retention of Temporal Sequence, Spatial  
Location, and Item Magnitude Information

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SHORT TERM RETENTION OF TEMPORAL SEQUENCE,  
SPATIAL LOCATION, AND ITEM MAGNITUDE INFORMATION

by

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B.A., Park College, 1978

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A thesis submitted to the  
faculty of the Graduate School of the  
University of Colorado in partial fulfillment  
of the requirements for the degree of

Master of Arts

Department of Psychology

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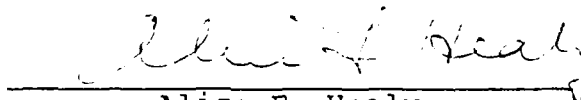
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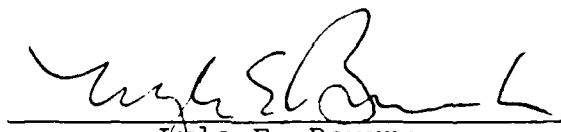
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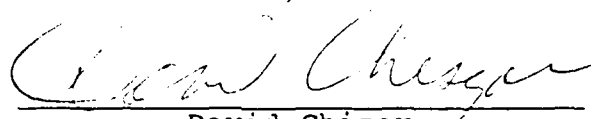
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Scheall, Michael James (M.A., Psychology)

Short Term Retention of Temporal Sequence, Spatial  
Location, and Item Magnitude Information

Thesis directed by Professor Alice F. Healy

Four experiments are designed to determine if differences exist in coding processes and time course of retention loss during short-term recall conditions, and the hypothesis that temporal sequence, spatial location, and item magnitude (size) information are each retained in short-term memory through specific visual and acoustic coding strategies is evaluated. Ninety-six undergraduate students read aloud computer generated displays of letters presented in three blocks of 24 trials during which targets appear under one of three variable conditions according to temporal sequence, spatial location, or item magnitude followed by a retention interval (0, 1.5, 6, or 18 seconds) during which intervening digits are displayed and vocalized by the subject to prevent rehearsal. During the first experiment, nonconfusable letters were presented, whereas in the second experiment, visually and acoustically confusable target letters were presented to evaluate the extent of phonetic coding among conditions. In the third experiment, articulatory suppression is induced and phonetic coding is prevented through the verbalization of a

prebriefed keyword rather than actual target identification. In the fourth experiment, visual discrimination interference is induced by replacing the target letters assigned to each trajectory with an "X" to determine the extent to which visual coding strategies facilitate short-term retention. Analyses of results of the first two experiments revealed significantly higher retention loss during spatial information conditions during both short and long delay intervals for both experiments. Retention loss with interval increase during the second experiment was highest during the temporal condition and strongly indicates the presence of a phonetic coding strategy. The third experiment introduced acoustic suppression during stimuli presentation and disrupted phonetic coding strategies with resultant means significantly higher than when acoustic suppression is not present. Two additional retention intervals used in the fourth experiment indicate that coding during spatial and item conditions occurs during the first 1500 milliseconds of the retention interval as distractor digits appear. Suppression of target distinction by unique appearance did not result in a significant retention loss during Experiment 4.

they were actually interested, and provided many helpful comments in interpreting some otherwise perplexing data.

For the support, understanding, and patience I received from my wife Maureen, I am forever grateful. Thanks Reen.

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I am grateful to the members of the skills group who listened to my presentations, acted like

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## CHAPTER I

### INTRODUCTION

Many models have been proposed to account for short-term recall of temporally coded stimuli and associated decay and interference over short retention intervals, particularly concerning the role of phonetic coding in the retention of temporal information (see, e.g., Atkinson and Shiffrin, 1968, Conrad, 1967, Estes, 1969, 1972, Healy, 1974, 1975a, 1975b, 1977, 1978, Murdock, 1969). Situations outside the laboratory setting generally involve both temporal and spatial information, but models pertaining to short-term retention of spatial information are less common (see Healy, 1975b, 1978). A third dimension concerning item information (verbal labels or visual characteristics such as shape or size which make objects discernable) has also been investigated in the laboratory setting, generally in a context which attempts to differentiate coding patterns between item and order information (see Bjork & Healy, 1974, Healy, 1974, 1975a, 1975b, 1982, Katz, Healy, & Shankweiler, 1983). In these investigations, a steep retention function and preponderance of

phonetic confusion errors for temporal recall was found, providing evidence for phonetic coding under this condition. This was not the case for spatial order recall, which was less affected by articulatory suppression, but disrupted when interpolated tasks requiring processing of spatial information were introduced. Item information in many of these studies (see e. g., Healy, 1975b) was held constant, where subjects knew the identity of items in advance, and only the order of the items had to be recalled.

In a recent study (Healy, Cunningham, Gesi, Till and Bourne (in press), the question of whether short-term retention of item information involves phonetic coding similar to that of temporal information was investigated. Although a similar investigation was accomplished by Healy (1977), no evidence was found to support the use of phonetic coding of item information. In that study, item information was recalled according to spatial order, which may have biased subjects against the use of a phonetic coding strategy. Healy et al. (in press) implemented controls for such bias, where temporal and spatial information were held constant when item information was to be recalled.

The four experiments included in this study

have been designed to investigate pattern coding processes during temporal, spatial and item conditions. These experiments are variations on earlier studies which date back to Conrad (1967) and Estes (1969), but are in large a product based on the investigations conducted by Healy (1974, 1975a, 1975b, 1977, 1978, 1982), and particularly the design found in Healy et al. (in press). In that study, the retention of item information was evaluated and compared to temporal and spatial information retention to determine the role of phonetic coding under each condition.

Under conditions which do not require the ordering of item information according to spatial location, a phonetic coding strategy may in fact become primary. This was investigated in Healy et al. (in press), by controlling for or holding constant temporal and spatial information when item information was to be recalled. This technique was applied during an unpublished study (Till, Healy, Bourne, & Cunningham, 1986) to determine if differences existed in short-term memory for item, temporal, and spatial information in young and elderly adults. In that study, age differences were largest under spatial order recall, somewhat smaller for temporal order

recall, and absent for the recall of item information.

In Healy et al. (in press), a similar comparison was conducted to determine if a selective disadvantage for spatial order recall exists in young children, where immature development would account for a similar decrement in memory processes attributable to aging. Results of those experiments indicate that retention of item information is associated with phonetic coding, which is disrupted when subjects are required to state the position in which the item appears rather than the names of the to-be-remembered items, a finding that could not be reached in previous studies where item information was coupled to spatial order recall (Healy, 1977).

The methodology used in this project results from a combination of procedures which have been employed in previous experiments concerning temporal-spatial relationships, and item-order relationships. Through combining and modifying these procedures, a model which compares temporal sequence, spatial location, and item magnitude (size) coding processes is possible. This project compares information loss between conditions as well as information loss within each condition over short and long retention intervals. This methodology also incorporates

analyses which permit investigation of coding processes which are primary to each condition. Specifically, an analysis of serial position error is conducted to determine if primacy and recency effects are factors in this design, and an analysis of confusion error is conducted in each experiment where visually and phonetically confusable stimuli are presented.

The first experiment of this study was designed to determine the coding processes found in discriminating between item information, the magnitude or size of targets as they appear on a computer monitor, and how these coding processes compare to those primary to temporal order and spatial location conditions. Replicating techniques by Healy (1975b, 1977) and Katz et al. (1983), successive visual presentations of a set of stimulus items occurs, followed by the subject's response based on the condition under investigation. The same set of items is used across trials, and the subject is briefed prior to each block of trials on which target letters will be appearing. As a specific target is assigned to a particular plane or trajectory for the entire experiment, the subject is not required to remember the items themselves, but rather the ordering

according to condition. In the temporal sequence recall condition, spatial location of each target letter is held constant across trials, as is item magnitude, so that the subject is aware of the position in which a target will appear and the size it will be, and consequently may direct attention primarily toward recall according to temporal sequence or appearance of the target. Likewise under the remaining two conditions, only the information to-be-recalled varies across trials, while the information not under investigation is held constant. This methodology separately assesses the three aspects of short-term recall in this study through careful control of the variables not under investigation while providing a relatively "pure" representation of recall according to the type of information to be remembered. This methodology extends to all experiments in this study.

A second experiment was developed to determine if presentation of phonetically and visually confusable targets further confound the task according to condition. We expected to find further evidence of phonetic coding under temporal recall conditions through an analysis of confusion errors, where targets which are phonetically confusable result in a larger

number of transpositions than targets with no phonetic similarity. Visually similar targets were introduced into this experiment to determine if targets may be coded to an extent by appearance. The analysis of confusion errors is expected to result in a higher number of visual confusion errors if such a strategy is used in coding.

In the study by Healy (1975b), evidence of a temporal-spatial coding strategy was reported when phonetic coding was hampered. We expected similar findings in the third experiment of this study through the introduction of acoustic suppression as targets appeared. If subjects revert to an alternate temporal-spatial coding scheme based on the pattern of the display, we would expect to see an overall performance decrease, particularly under the temporal condition, where phonetic coding is generally chosen as a primary strategy. Target presentation during the experiments of this study are markedly different from previous studies in that only three letters are used in any block of trials, and each letter is assigned to a specific plane or trajectory, either left, middle or right. The subject must enter the response as appropriate to the condition being tested, and in the briefed order. Previously, subjects were permitted to

enter a response in the order they chose, for example, on a card with four blanks to be filled in they could choose to enter an answer in the third position first. This is not the case in the current study, where subjects must answer according to a specific order, largest to smallest, first to last, or closest to farthest, dependant on the condition being tested. As no such restriction was imposed in previous studies, we have no clear basis as to the effectiveness of a temporal-spatial coding strategy concerning the current methodology.

The fourth and final experiment of this study was designed to determine the extent to which visual coding according to target appearance is employed under the methodology found in the first three experiments. Rather than assigning a specific target letter to a given plane or trajectory, all targets appear as the letter "X", with the only distinction between targets being the magnitude or size of the targets, either one, two or three letters. This method is similar to that used by Healy (1982), which was designed to determine the extent to which pattern coding is used. Using this form of target presentation is expected to eliminate phonetic coding as well as introduce visual confusability, and force

the subject into a temporal-spatial coding strategy.

Two additional retention intervals were added during the fourth experiment, one to determine if a ceiling effect exists when no distractor digits appear (a zero retention interval), and one consisting of an interval of 36 intervening digits to further evaluate the effects of retention loss over time and to determine if such a loss is monotonic in nature.

Both the third and fourth experiments have been divided into two parts, to provide a comparison of performance to the conditions of the second experiment while accounting for effects attributable to the change in subject pools, as the final two experiments were run one year after the first two experiments.

## CHAPTER II

### EXPERIMENT 1

The method used in Experiment 1 is a modification of procedures by Katz et al. (1983), and Healy (1974, 1975b), to compare short-term memory for item, temporal order, and spatial order information. All three types of information are compared in this study, as in Healy et al. (in press). A primary difference exists between the presentation of stimuli in this study and previous studies, where stimuli appear in an assigned sector of the computer screen as opposed to a single binaview cell or horizontal array as in Estes (1969, 1972) and Healy (1974, 1975b).

Computer generated stimuli containing distinguishable temporal order, spatial location, and item size (magnitude) information were presented sequentially to subjects. There were 24 trials in each of the three blocks of recall conditions. For the temporal order recall condition, the subjects were instructed to report the temporal sequence of three target presentations, during which spatial and size information were constant and known by the subject. Likewise, in the spatial order recall condition, the

subjects were aware of constant temporal sequence and size information to be displayed and reported target spatial location information. For the size order recall condition, temporal and spatial conditions were constant and the subject reported information based on target size. A distractor task consisting of verbalization of a set of numbers presented immediately after the target presentation sequence was utilized. Subjects then entered the response according to the specific order of information to be recalled for that trial. The computer keyboard was modified so that three keys, each representing one of the three planes used in presenting target stimuli, were isolated by removal of surrounding the keys. Specifically, the standard keyboard letters "C", "T", and "B" were removed and replaced with the letters "A", "B", and "C", and all keys adjacent to those keys were removed. The order of tasks was counterbalanced across subjects, and each subject participated in all three memory tasks. The amount of information to be recalled was equated for the three tasks, and each subject viewed the same stimulus files so that the ordering of retention intervals (3 or 12 digits) and the sequence of distractor digits was the same for each subject.

The area of primary interest in this experiment concerns the comparison of item information to the other two memory tasks. A steep retention function during the temporal condition is expected relative to the spatial task if findings are in accordance with previous studies. Also of interest is the possible effects associated with a change in the method of presenting stimuli, which now appear in specific trajectories on the screen rather than three adjacent horizontal slots as in Healy et al. (in press). This method of presentation may facilitate a temporal-spatial coding scheme which interferes with other strategies, particularly phonetic coding, found in previous studies.

#### Method

Subjects. Twenty-four subjects were drawn from the Introductory Psychology subject pool and consisted of sixteen female and eight male subjects. Each subject served in a single 25-minute session during which all three information conditions were presented. Subjects were participating to receive credit required by the psychology course they were enrolled in.

Apparatus and materials. A computer

simulation of a geographic domain, consisting of an array including a single "base" location which represents the subject's position, and three trajectories, each a distinct plane in relation to the base location, was prepared using the PDP-11 and VT100 terminal. The base location was represented by a marking (an "@" symbol) at a fixed point located at the bottom center of the CRT screen. Of the three trajectories, one was located directly to the left of the base location, one directly above, and one directly to the right. Within a given trajectory, a target could appear in one of three positions. An example of the computer display showing all three trajectories is shown in Figure 2.1, though in each experiment only one trajectory is displayed at a time.

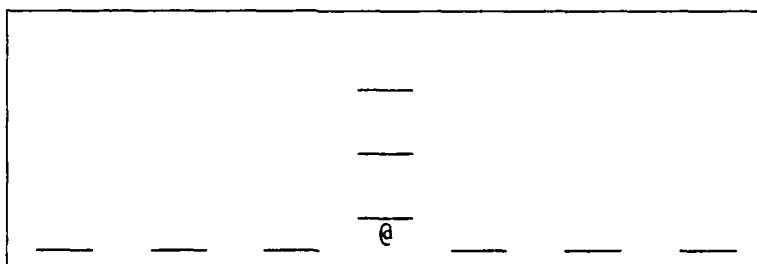


Figure 2.1

Example of trajectory locations in which targets appear during all conditions of all experiments in this study

Within a given trajectory, a target appears at one of the three distinct positions on the same plane.

Each trial consists of three targets appearing one at a time, with one target per trajectory.

Three different 24-trial sequences were devised, with a trial consisting of a three-target stimulus followed by a retention interval of 3 or 12 intervening digits (Katz et al. 1983, Healy et al. in press). The letters and digits were presented successively, the letters each in a different one of three planes in relation to the base location, and the digits appearing in the position of the base location. Positions not containing letters in each plane were represented by dashed lines. Target size was approximately 4mm by 2mm, and targets and distractor items appeared at fixed intervals of 500 msec.

The letters presented were permutations of the set A, B, and C, in capitals, with certain variations dependent upon the type of information being presented. For temporal information trials the targets appeared as AAA, BB, and C. The targets were presented in the same plane and in the same spatial position, with the target AAA appearing in the left plane and closest to the base location, target BB appearing in the center or vertical plane in the position second closest to the base position, and

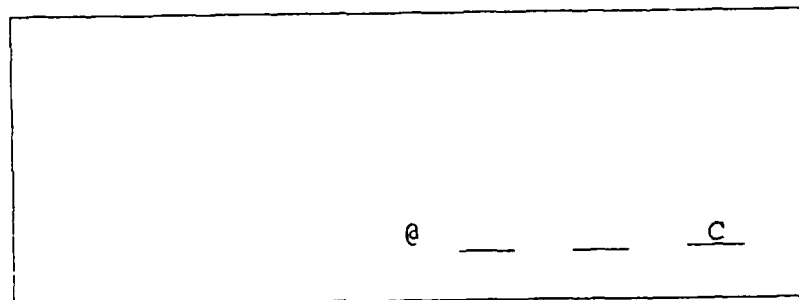
target C appearing in the plane to the right of the base position and in the position farthest from the base location. Only the temporal sequence was varied during the 24 trials (see Figure 2.2).

During the spatial information trials, the targets again appeared as AAA, BB, and C. Temporal order was held constant so that targets always appeared in the order A-B-C, and only spatial information, that is, target location, was varied so that the target AAA could appear in any of the three positions on the plane to the left of the base location, target BB could appear in any of the three positions in the center or vertical plane, and target C could appear in any of the three positions on the plane to the right of the base location (see Figure 2.3).

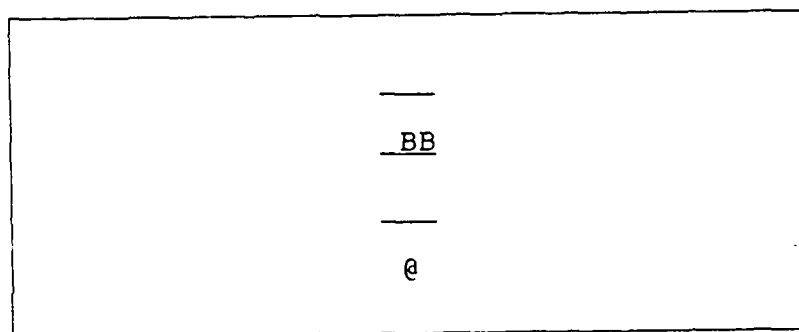
For the item (target size) information trials, target location and order of presentation were constant, and only size of target was varied. For this block of trials, the following six permutations were presented:

AAA BB C, AAA B CC, AA B CCC, AA BBB C, A BBB CC  
AND A BB CCC.

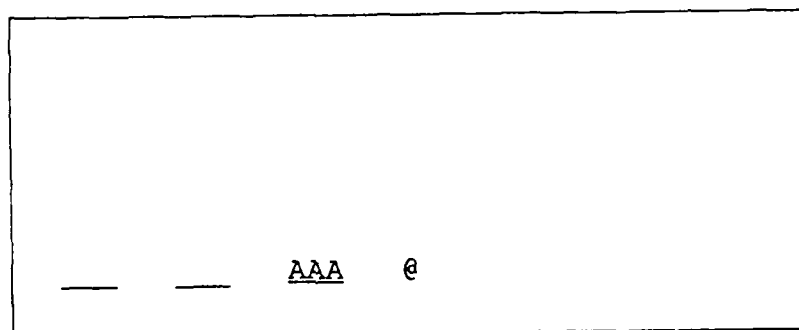
Target "A" was located on the plane to the left and in the position closest to the base location, target "B"



Frame 1



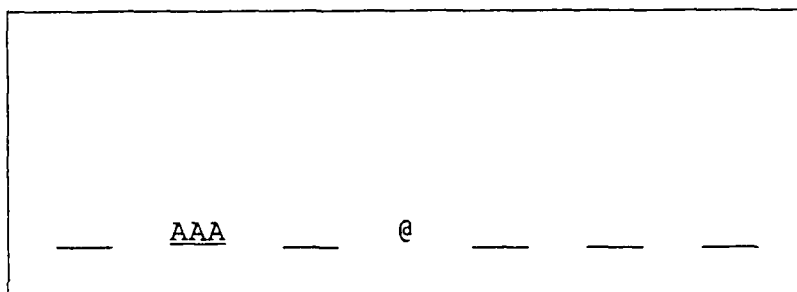
Frame 2



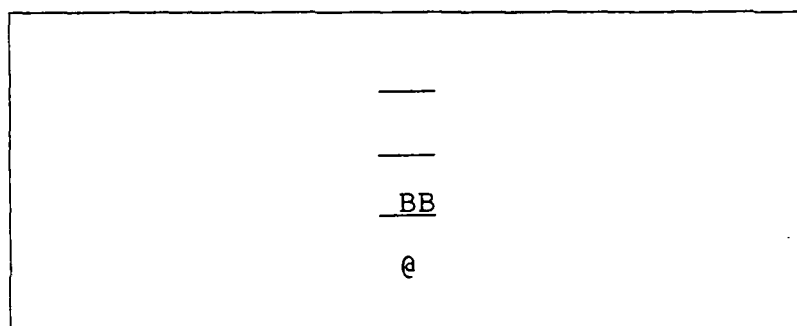
Frame 3

Figure 2.2

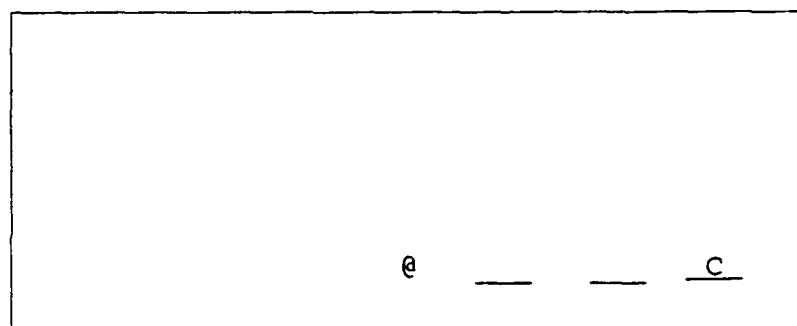
Sample presentation of temporal condition trial  
 as frames appear on the computer screen  
 (Correct response is "C, B, A")



Frame 1



Frame 2



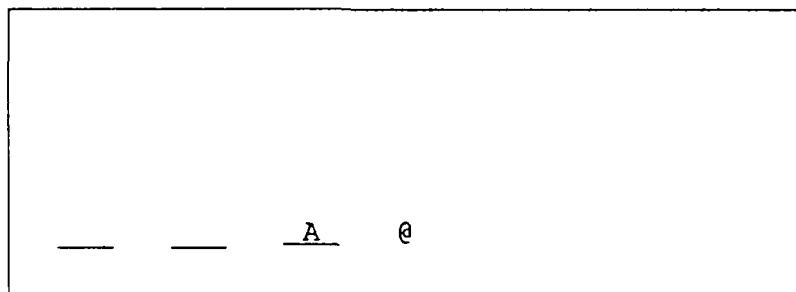
Frame 3

Figure 2.3

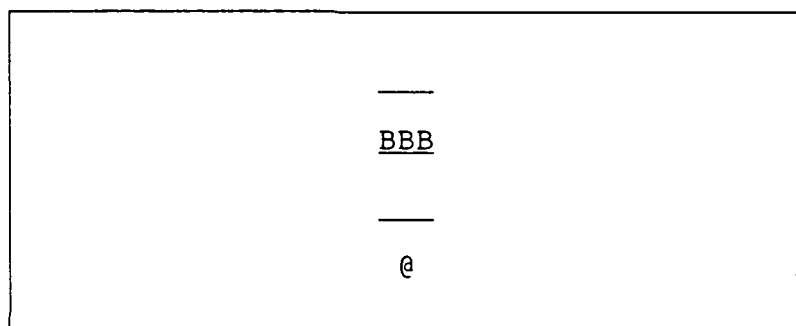
Sample presentation of spatial condition trial  
as frames appear on the computer screen  
(Correct response is "B, A, C")

was located on the center or vertical plane in the position second closest to the base location, and target "C" was located on the plane to the right and farthest from the base location (see Figure 2.4). Temporal sequence A-B-C was constant in this condition.

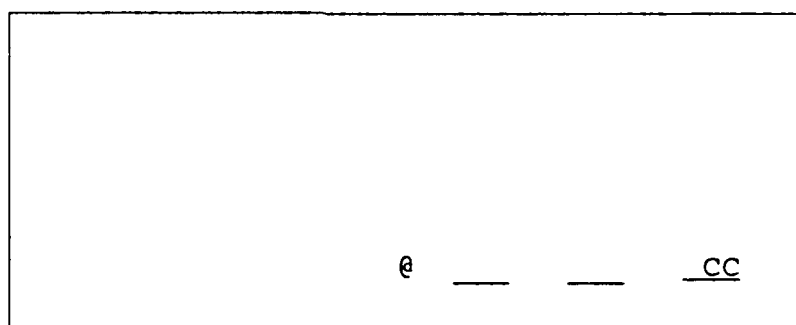
The intervening digits for all trials were selected from the set: 4, 6, 8, presented in three's, (e.g. "444", "666", "888") so that they are easily seen at a 500 ms presentation rate, but read aloud as if only one digit appeared. Selection was to match the digit sequence used in previously conducted similar experiments with temporal and spatial order information (Katz et al., 1983). No digit occurred in two successive displays, and each digit occurred equally often in every group of two successively presented sets. For all trials, targets using the letter "A" appeared in the plane to the left of the base position, "B" appeared in the plane above the base position, and "C" appeared in the plane to the right of the base position. During each block of twenty-four trials, each of the six permutations of the set A-B-C corresponded to the correct response four times, twice at each retention interval. Responses were recorded through the use of the



Frame 1



Frame 2



Frame 3

Figure 2.4

Sample presentation of item (magnitude) condition  
 trial as frames appear on the computer screen  
 (Correct response is "B, C, A")

computer keyboard, which was modified so that the A, B, and C keys were positioned to represent spatially the three trajectories presented. Separate files were recorded by the computer for each subject and included both the response and reaction times for each trial.

Design and procedure. The subjects were tested individually in three 8-min blocks. Each block was devoted to one recall condition. A graphic representation was shown to the subject of how the three trajectories would look if they were displayed at the same time rather than individually so the subject was aware of trajectory location. The subject was provided an instruction sheet specific to the type of information being tested, and the instructions were read out loud by the experimenter as the subject read along. Subjects were informed of the information held constant in that particular set of trials. The subject was then presented six practice trials which provided each of the possible permutations to be used in that series of trials and an equal number of short and long retention intervals. The subject was then presented 24 trials, each successive trial beginning immediately after the subject's answer was entered on the keyboard.

To provide counterbalancing of condition

order, each successive subject was presented either temporal, spatial, or item (size) information trials according to a randomly arranged order of the 6 possible permutations of the types of trials available (TSI, TIS, STI, SIT, ITS, IST). Each of these permutations appeared four times among the 24 subjects.

Data scoring. Responses were recorded by the computer as the subject entered them on the keyboard. Data were scored by hand to determine the proportion of incorrect trials, and further analyzed for response error according to the serial position in which the error occurred according to the retention interval for each trial, grouping short intervals and long intervals by condition. A total transposition error, where none of the target letters was entered in it's correct position during the response, was scored as an error for all three positions. The error for each position was calculated and converted to a total proportion correct for each position, by condition and retention interval.

### Results

All data were converted to proportions according to the number of errors per condition

(temporal, spatial or item) and length of the retention interval (3 digit or 12 digit). The results for each recall condition are summarized in Figure 2.5 in terms of proportions of correct responses according to condition (temporal, spatial or item) and short and long retention interval within each condition.

Two comparisons are of primary concern: (a) the comparison between the level of performance in the three types of tasks (temporal, spatial, and item recall); and (b) the comparison between the levels of performance for each condition contingent upon the length of the retention interval. An analysis of variance yielded a statistically reliable main effect of condition,  $F(2,46)=4.54$ ,  $MSE=.029$ ,  $p<.016$ , with performance being poorest overall in the spatial recall condition. A decrease in performance as retention interval increases is apparent in the temporal and item conditions; however, the recall probability between retention intervals in the spatial condition shows no decrement in performance with an increase in the retention interval, and the main effect of retention interval was marginally significant,  $F(1, 23)=2.89$ ,  $MSE=.0080$ ,  $p=.09938$ . A significant interaction of condition and retention interval was found,  $F(2, 46)=3.99$ ,  $MSE=.0064$ ,  $p<.025$ , which is consistent with earlier studies comparing temporal

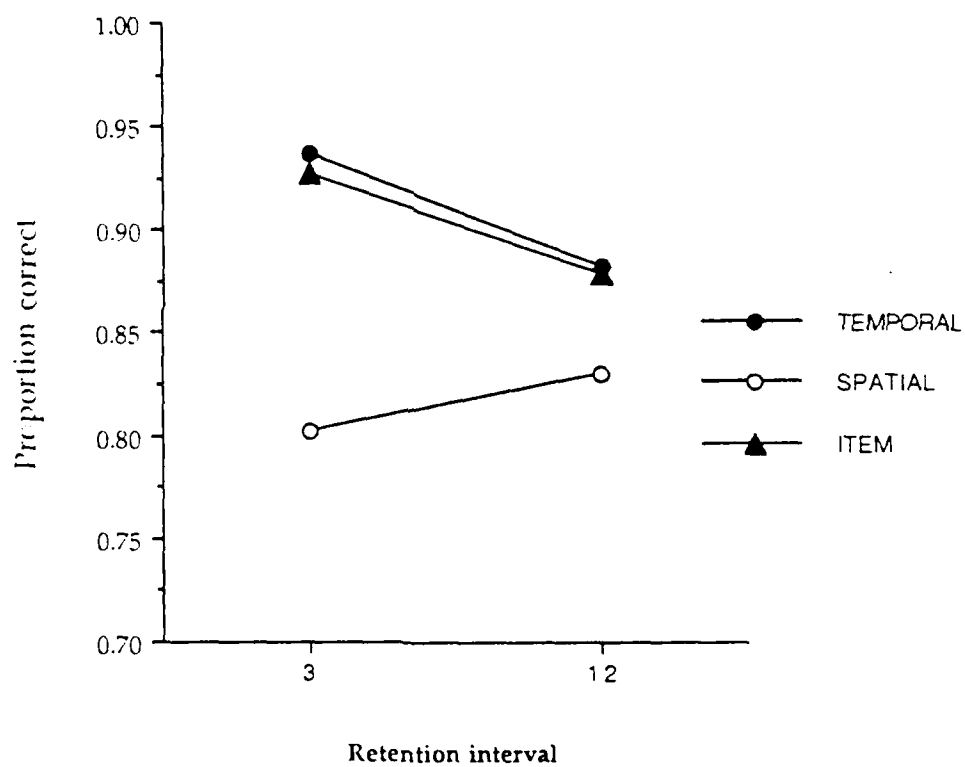


Figure 2.5

Proportion correct in the temporal, spatial, and item conditions by retention interval, Experiment 1.

sequence and spatial location recall (for example, Healy, 1975, 1977, 1978), where there was an overall decline in performance with retention interval, though much greater for temporal sequence than spatial location recall.

An analysis of serial position effects is presented in Table 2.1. This analysis shows that bow-shaped curves occurred in all three conditions and at both retention intervals. In every case, recall of targets appearing in the second position was less

Table 2.1

Proportion Correct in Each Recall Condition by Serial Position, Experiment 1

	<u>Position</u>					
	1		2		3	
<u>Retention Interval:</u>	3	12	3	12	3	12
<u>Condition</u>						
Temporal	.951	.910	.945	.885	.965	.913
Spatial	.868	.879	.809	.851	.843	.885
Item	.955	.927	.931	.882	.962	.920

accurate than that of targets appearing in the first and third positions, with a main effect of position of  $F(2, 46)=9.825$ ,  $MSE=.0049$ ,  $p<.0005$ , and a main effect of retention interval  $F(1, 23)=4.09$ ,  $MSE=.0156$ ,  $p<.053$ . A

significant two-way interaction between positions dependant on retention interval and condition was also found,  $F(2, 46)=4.419$ ,  $MSE=.0106$ ,  $p<.018$ .

### Discussion

The addition of a third condition of recall information (item or object size) to a task comparing temporal sequence recall and spatial location recall resulted in nearly identical performance in temporal and item conditions. This finding suggests similar strategies are employed during temporal and item conditions which rely more on phonetic coding than does the strategy employed during the spatial location recall condition. This result is consistent with findings from Healy (1975b), where evidence of phonetic coding was found during temporal conditions but not under spatial conditions. The similarity of performance between temporal and item conditions is contrary to our expectations, as the task involved during the item condition more closely resembles the task performed during spatial conditions, where the target must be evaluated as it appears and converted into the appropriate sequence required by the response. During the temporal condition, this problem does not exist because targets appear in the order appropriate to the response, and no conversion must be performed. This

accounts for the effectiveness of phonetic coding during temporal conditions, but does not account for item information results where phonetic coding of object size appears equally effective.

Previous findings that spatial order recall involves the use of nonphonetic coding (e.g., Healy, 1975b) are apparent in this experiment, which is demonstrated through the disruption of phonetic coding strategies through the use of a verbalized distractor paradigm. The absence of the characteristic decrease in performance with an increased retention interval indicates that a nonphonetic coding process is primary under this condition. It is not clear why a similar process is not employed during item information conditions.

## CHAPTER III

### EXPERIMENT 2

In Experiment 1 item information recall was nearly identical to recall under temporal conditions, with both showing a steep retention function indicative of a phonetic coding strategy. Recall of spatial location information resulted in a relatively flat condition across retention intervals, suggesting that a different coding strategy was employed by subjects under that condition. The present experiment was designed to provide insight into the degree to which subjects employ phonetic coding by introducing targets which may be confused phonetically as well as visually. These letters, F, P, and V, replicate the stimuli found in Katz et al. (1983), with F and P being visually confusable, and the letters P and V being phonetically confusable. If phonetic coding is a primary strategy under a specific condition, as suspected during the temporal condition of the first experiment, we would expect a higher proportion of errors to occur where the letters P and V are transposed. Also of interest is the degree to which visual coding is used under the same conditions, and it is expected that a higher proportion of confusion errors

between the letters F and P would indicate that visual coding is being employed.

### Method

Subjects. Twenty-four new subjects were drawn from the Introductory Psychology subject pool. Sessions were conducted in the same manner as in the first experiment. Thirteen male and eleven female subjects participated.

Materials. In this experiment, the letters presented were permutations of the set F, P, and V, in capitals, with certain variations dependent upon the type of information being presented. For temporal information trials the targets appeared as FFF, PP, and V. The targets were presented in the same planes and same spatial positions as in Experiment 1, with the target FFF appearing in the left plane and closest to the base location, target PP appearing in the center or vertical plane in the position second closest to the base position, and target V appearing in the plane to the right of the base position and in the position farthest from the base location. Only the temporal sequence was varied during the 24 trials.

During the spatial information trials, the targets again appeared as FFF, PP, and V. Temporal order

was held constant so that targets always appeared in the order F-P-V, and only spatial information, that is, target location, was varied so that the target FFF could appear in any of the three positions on the plane to the left of the base location, target PP could appear in any of the three positions in the center or vertical plane, and target V could appear in any of the three positions on the plane to the right of the base location. For the item (target size) information trials, target location and order of presentation were constant, and only size of target was varied. For this block of trials, the following six permutations were presented:

FFF PP V, FFF P VV, FF P VVV, FF PPP V, F PPP VV  
and F PP VVV.

Target F was located on the plane to the left and in the position closest to the base location, target P was located on the center or vertical plane in the position second closest to the base location, and target V was located on the plane to the right and farthest from the base location. Temporal order was held constant at F-P-V.

The intervening digits and randomization procedures employed for all trials were identical in nature to those used in the first experiment. The targets F, P and V were selected for this experiment

because the design calls for a condition between targets which provides a "confusable" and "control" relationship (see Katz et al., 1983). The "confusable" relationship is either visual or acoustic. Using the target letters F, P and V, the visual confusion occurs between the similar appearance of the letters F and P. The acoustic confusion occurs between the phonetic similarity of the names of the letters P and V. The control set consists of the letters F and V, where no phonetic or visual similarity exists between letters. As every trial consisted of the target letters F, P and V, each response was subject to visual and acoustic confusion errors, which differentiates this experiment from the first, where the target letters A, B, and C were employed and no visual confusion was induced, though phonetic confusion error existed between the letters B and C.

Design and procedure. The testing sessions in the present experiment were conducted in the same manner as in the first experiment. The only difference between the first and second experiments was in the target presentation, where the target letters A, B, and C in the first experiment were replaced with the letters F, P and V in this experiment. Four categories of error are possible in this experiment. Acoustic errors are scored when the letters "P" and "V" are transposed. Visual

errors are scored when the letters "F" and "P" are transposed. Compound errors consist of a complete transposition of letters, none appearing in its correct position, and control errors exist when the subject transposes the letters "F" and "V". These errors are recorded for each condition and retention interval so that a comparison of confusion errors is possible.

Data scoring. Responses were recorded by the computer as the subject entered them on the keyboard. Data were analyzed for response error according to the serial position in which the error occurred, and the analysis was further divided according to the retention interval for each trial, grouping short intervals and long intervals.

### Results

The results of the present experiment are summarized in Figure 3.1 in terms of percentages of correct responses according to condition (temporal, spatial or item), and short and long retention interval within each condition.

Though a significant difference exists in proportions of correct responses between temporal and spatial conditions,  $F(1, 46)=4.60$ ,  $p < .05$ , an omnibus comparison of means does not reveal a significant main

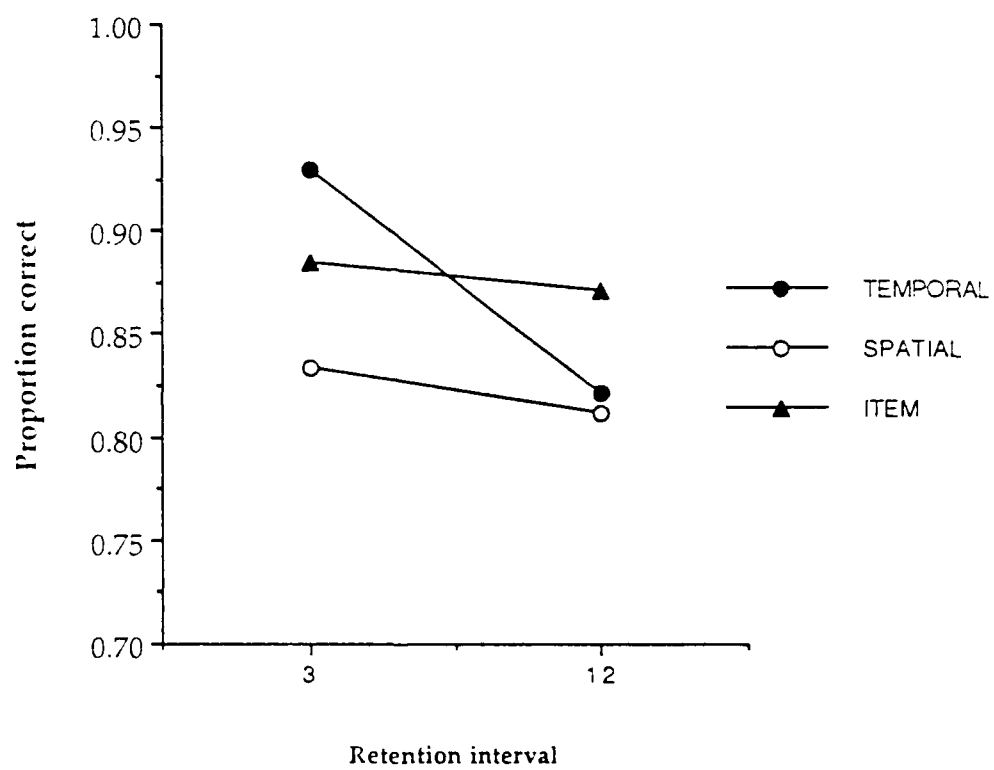


Figure 3.1

Proportion correct in the temporal, spatial, and item conditions by retention interval, Experiment 2.

effect of condition. There was a significant decrement in performance between retention intervals,  $F(1, 23)=6.38$ ,  $MSE=.0127$ ,  $p<.018$ , and a significant interaction of condition and retention interval was found,  $F(2, 46)=3.56$ ,  $MSE=.0092$ ,  $p<.036$ . As in the first experiment, performance during the temporal condition decreased as retention interval increased, indicating that the primary coding strategy during this condition is phonetic in nature.

The spatial and item conditions resulted in means between retention intervals within each condition which are nearly equal, which suggests that with no loss over increased retention interval, a coding process other than phonetic is primary. The performance under item information conditions now shows a leveling across retention intervals, indicating that the primary coding process is now nonphonetic, and perhaps similar to the process found during the spatial condition. This change may be attributable to the change in target presentations, which are now visually and acoustically confusable.

Visually and acoustically confusable target letters were used to provide further insight into the primary coding processes employed under each condition. The breakdown of error proportions by condition,

Table 3.1

Proportion of Errors that Reflect Letter Set  
Transpositions in Experiment 2 by Condition, Retention  
Interval, and Letter Set.

Condition	<u>Number of intervening digits</u>	
	3	12
Temporal		
Control	.042	.153
Acoustically confusable	.056	.153
Visually confusable	.083	.181
Compound error	.097	.236
Spatial		
Control	.157	.108
Acoustically confusable	.098	.088
Visually confusable	.128	.137
Compound error	.108	.177
Item (size)		
Control	.119	.048
Acoustically confusable	.083	.095
Visually confusable	.060	.167
Compound error	.202	.226

retention interval, and type of error may be found in Table 3.1. The compound error, which necessarily includes an acoustic, visual and control error, comprised the largest single type of error across conditions. Interestingly, there are not more acoustic confusion than visual confusion errors in the temporal condition, contrary to the hypothesis that phonetic coding is used primarily in that case. In fact, acoustic confusions are greater than visual confusion only at the shortest retention interval in the item condition. Perhaps this lack of support for this hypothesis is due to the fact that most errors were compound in this experiment, where a total transposition of letters existed, and attributing this type of error to visual or acoustic interference is not possible from the information available.

An analysis of serial position errors is presented in Table 3.2. This analysis shows that bow-shaped curves occurred in all three conditions and at both retention intervals. In every case, and as in Experiment 1, recall of targets appearing in the second position was less accurate than that of targets appearing in the first and third positions, with a significant main effect of position error,  $F(2, 46)=4.58$ ,  $MSE=.0122$ ,  $p<0.16$ , and a two way interaction of condition and

retention interval,  $F(2, 46)=3.948$ ,  $MSE=.0418$ ,  $p<.026$ .

Table 3.2

Proportion Correct in Each Recall Condition by Serial Position in Experiment 2

	<u>Position</u>					
	1		2		3	
<u>Retention Interval:</u>	3	12	3	12	3	12
<u>Condition</u>						
Temporal	.951	.875	.931	.833	.955	.872
Spatial	.889	.872	.854	.809	.899	.868
Item	.986	.879	.879	.847	.896	.896

### Discussion

The results of the second experiment are consistent with those of the first experiment in that recall during the spatial location recall condition is not as accurate as during the temporal sequence condition. The temporal condition shows a significant decrease as retention interval increases in both experiments, suggesting that phonetic coding is the primary process in this condition. Under item information recall conditions, a loss occurred as retention interval increased in the first experiment, but not the second, where visual and acoustic confusion were introduced. This finding suggests that phonetic coding is primary when targets are nonconfusable, and that a

nonphonetic coding process is employed when targets are visually or phonetically confusable. This result is contrary to original expectations that similar coding processes would be found between item and spatial conditions. Spatial recall was lower than item and showed no loss over increase in retention interval in both experiments. These findings are similar to previous studies concerning alternate coding schemes and the use of a nonphonetic coding of vocalized items (Healy, 1975b), where temporal-spatial pattern coding exists in short-term retention of spatial order information.

The important point made by this research is that the addition of a form of information which determines object differentiation through size discrimination resulted in coding patterns which are similar to those used in coding temporal information when items are neither visually nor acoustically confusable, and when such confusion does exist, a nonphonetic coding process becomes the primary process. The flexibility of changing coding strategies when visual and phonetic confusion is introduced into the task is unique during size discrimination, and the results of this study suggest that flexibility of change is constrained during temporal and spatial conditions, even though a change in coding processes might be more effective.

## CHAPTER IV

### EXPERIMENT 3

Experiment 3 introduces articulatory suppression by preventing vocalization of the target as it appears on the screen, requiring the exclusive use of visual coding during all three conditions (see Healy, 1975b). This suppression requires the subject to recall target information through the use of visual cues, and is accomplished by requiring the subject to vocalize a prebriefed word as each target appears. The primary coding process is expected to be spatial location encoding of the visual presentation according to the condition under investigation. With disruption of phonetic coding processes, it is expected that the means of all three conditions will be lower than those found in the first two experiments, where recall was perhaps facilitated to a degree by phonetic coding processes.

With the introduction of articulatory suppression, the strategy for coding the information required by each condition is expected to be one which involves recall by trajectory, or the plane in which the targets appear. Subjects in previous experiments reported that recall was easiest when responses were

paired with each of the three spatial planes, either left, middle or right. With the keyboard modified to represent these three planes (as in the previous two experiments), subjects often placed their fingers near the keys, with a finger on the key corresponding to the first desired response, and a finger near the key corresponding to the second response. An unlimited number of distractor digits may be read aloud using this strategy, as response becomes mechanical, based on finger position rather than recall of target appearance. This experiment disrupts the use of such a strategy by prohibiting the subject from prepositioning fingers on the keyboard, and fingers were permitted to be placed on the keys only after the last distractor digit for that trial appeared. This change is intended to disrupt spatial coding of responses under all three conditions, requiring the use of visual coding as the primary strategy.

### Method

Subjects. Twenty-four new subjects were drawn from the Introductory Psychology subject pool. Subjects were run individually, with 12 subjects assigned to a group where trials included articulatory suppression, and 12 subjects assigned to a group which replicated

Experiment 2 to account for changes associated with the change in subject pools between Experiments 2 and 3.

Materials. In this experiment, as in the second experiment, targets are permutations of the set F, P, and V, in capitals, with the same variations dependent upon the type of information being investigated. The intervening digits and randomization procedures employed for all trials were identical in nature to those of the second experiment. The targets F, P and V were selected for this experiment because the design calls for a condition between targets which provides a "confusable" and "control" relationship. The "confusable" relationship should be limited to visual confusion in this experiment, where using the target letters F, P and V, visual confusion is possible between the similar appearance of the letters F and P. Acoustic confusion is controlled through requiring the subject to say the word "red" rather than actual target letter identification as it appears on the screen. The control set consists of the letters F and V, where no phonetic or visual similarity exists between letters. As every trial consisted of the target letters F, P and V, each response was subject to visual confusion errors, which differentiates this portion of the experiment from the second, where the target letters F, P, and V were read

aloud as they appeared (as in Experiment 2), providing the opportunity for phonetic coding and phonetic confusability of the letters P and V, which have similar names.

Design and procedure. The testing sessions in the present experiment were conducted in the same manner as in the second experiment, with the exception that a change in the target vocalization by the subject is introduced to prevent phonetic rehearsal, with the subject saying aloud the word "red" rather than the actual target name of "F", "P" or "V". The first twelve subjects were run under these conditions, after which the procedure of vocalizing the word "red" was reverted back to reading the target as it appears, as in the second experiment. This switch was necessitated by a change in subject pools and is intended to account for any effects associated with the use of a new subject pool. As this experiment was divided into two parts, the portion of the experiment which included acoustic suppression is identified as "Experiment 3A", whereas the portion of the experiment which replicated Experiment 2 to account for changes in the subject pool is identified as "Experiment 3B".

Data scoring. Responses were recorded by the

computer as the subject entered the response on the keyboard. Data were hand-scored to reflect the proportion of correct responses by condition and retention interval for each subject, as well as for confusion and serial position error. Response times were recorded by the computer, but were not used in scoring this experiment.

### Results

The data were analyzed as in the previous experiments in terms of the proportion of correct responses by both condition and serial position, and an analysis of confusion errors was conducted as in Experiment 2 to determine if the resulting retention loss was attributable to visual or phonetic errors. A significant difference in the overall performance between the two portions of this experiment was expected due to the acoustic suppression introduced in the first portion of the experiment. By prohibiting the subject from vocalizing the target identity as it appeared by requiring the word "red" to be spoken at each target appearance, a performance degradation seemed imperative. Contrary to our expectations, performance was significantly better in this portion of the experiment where acoustic suppression was introduced, with the analysis between these two portions of the experiment

resulting in an  $F(1, 22)=4.56$ ,  $MSE=.0447$ ,  $p=.042$ . No significant difference in means between conditions or retention loss as retention interval increased exists in 3A. The results (proportion correct) by condition and retention interval for each portion of this experiment are shown in Figures 4.1 and 4.2.

The second portion of this experiment (part 3B) was conducted to replicate Experiment 2, with the only difference being 12 subjects rather than 24. The results are very similar, with only a slight leveling occurring during the item condition as retention interval increased. A steep decrease in performance with retention interval increase is again apparent in the temporal condition,  $F(1, 11)=6.197$ ,  $MSE=.019$ ,  $p<.029$ , and though overall performance in the spatial condition remains lower than that found in the other two conditions, no significant differences in means were found when an omnibus analysis of condition was conducted.

An analysis of serial position error (proportion correct) by condition and retention interval between the two portions of this experiment (3A and 3B) resulted in a significant difference in position error,  $F(2, 44)=8.942$ ,  $MSE=.0026$ ,  $p=.0009$ , with the largest number of errors occurring in the second position. A bow shaped curve is

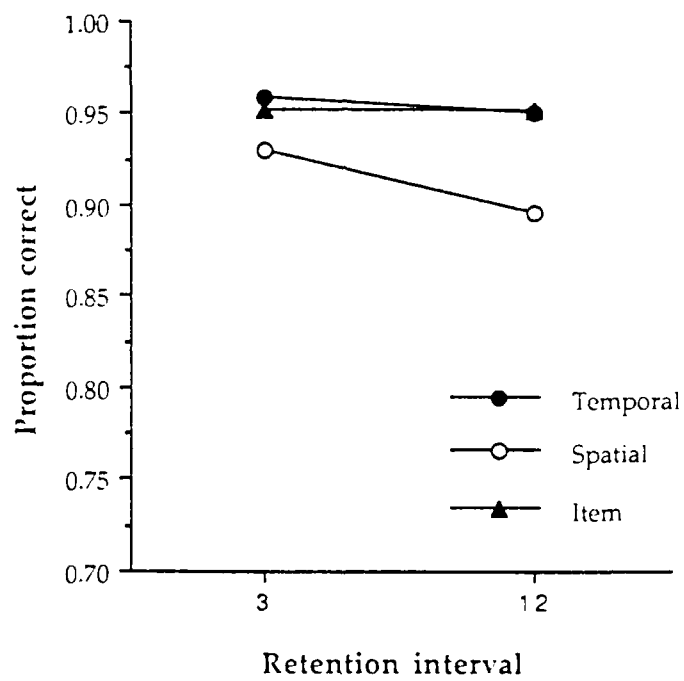


Figure 4.1

Proportion correct in the temporal, spatial  
and item conditions by retention interval,  
Experiment 3A.

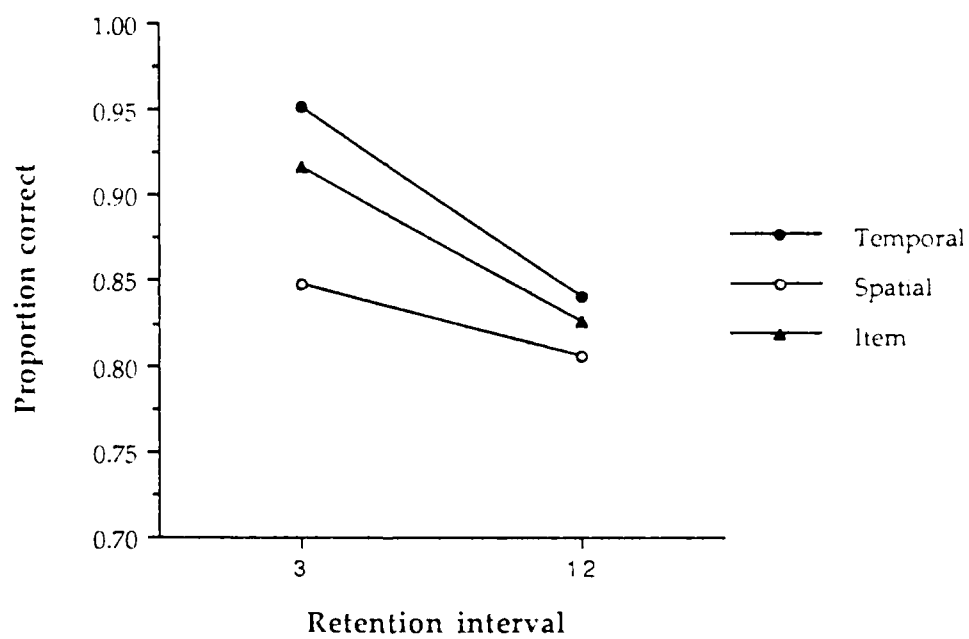


Figure 4.2

Proportion correct in the temporal, spatial, and item conditions by retention interval, Experiment 3B.

apparent in all but four instances, specifically the long retention interval of the temporal condition in 3B, and the short retention interval of the spatial condition in 3B, which were essentially flat and had equal error in each of the three positions, and the long interval of the item condition in 3A where positions 2 and 3 were nearly equal, and the short interval of the temporal condition interval of 3B, where positions 1 and 2 were identical. These results are shown in Tables 4.1 and 4.2.

Table 4.1

Proportion Correct in Each Recall Condition by Serial Position in Experiment 3A

	<u>Position</u>					
	1		2		3	
<u>Retention Interval:</u>	3	12	3	12	3	12
<u>Condition</u>						
Temporal	.972	.972	.958	.951	.979	.972
Spatial	.958	.931	.938	.889	.972	.910
Item	.958	.993	.938	.972	.958	.965

As in Experiment 2, an analysis of confusion error was conducted to determine if one of the four possible error types, (visual, acoustic, control or total transposition) is predominant, dependent upon the presence or absence of acoustic suppression. In the first part of this experiment, subjects vocalized the

Table 4.2

Proportion Correct in Each Recall Condition by Serial  
Position in Experiment 3B

	<u>Position</u>					
	1		2		3	
<u>Retention Interval:</u>	3	12	3	12	3	12
<u>Condition</u>						
Temporal	.958	.875	.958	.961	.986	.854
Spatial	.875	.868	.882	.826	.889	.875
Item	.958	.875	.917	.833	.944	.875

word "red" rather than the target letter that appeared. The use of a one-syllable word was intended to prevent any acoustic rehearsal which may be occurring during the retention interval as digits were read aloud, and to eliminate phonetic confusion error. It was expected that by preventing this type of rehearsal, the overall retention accuracy would be adversely affected and overall performance would be significantly lower under conditions where phonetic coding strategies were used, and error would be accounted for in the remaining three possible error types. The results of this analysis are shown in Tables 4.3 and 4.4.

In part 3A, the proportion of error under all conditions was less than .025, essentially demonstrating a ceiling effect, with no significant difference occurring between conditions or retention intervals. In

Table 4.3

Proportion of Errors that Reflect Letter Set Transpositions in Experiment 3A by Condition, Retention Interval, and Letter Set.

<u>Condition</u>	<u>Number of intervening digits</u>	
	<u>3</u>	<u>12</u>
Temporal		
Control (F, V)	.014	.014
Acoustically confusable (P, V)	.021	.007
Visually confusable (F, P)	.000	.021
Compound error	.007	.007
Spatial		
Control	.014	.014
Acoustically confusable	.007	.021
Visually confusable	.028	.028
Compound error	.014	.049
Item (size)		
Control	.014	.000
Acoustically confusable	.014	.007
Visually confusable	.014	.028
Compound error	.021	.000

Table 4.4

Percentage of Errors that Reflect Letter Set  
Transpositions in Experiment 3B by Condition, Retention  
Interval, and Letter Set.

<u>Condition</u>	<u>Number of intervening digits</u>	
	<u>3</u>	<u>12</u>
Temporal		
Control	.000	.021
Acoustically confusable	.007	.042
Visually confusable	.035	.014
Compound error	.021	.069
Spatial		
Control	.056	.049
Acoustically confusable	.035	.049
Visually confusable	.035	.035
Compound error	.035	.055
Item (size)		
Control	.035	.055
Acoustically confusable	.016	.037
Visually confusable	.032	.023
Compound error	.023	.067

part 3B, overall error was much higher, but again no significant difference was noted between types of confusion error. An analysis between both portions of this experiment revealed no significant differences in the types of confusion error, phonetic or acoustic, though an interaction exists indicating that the type of error is dependant on retention interval and portion of the experiment,  $F(3, 66)=3.52$ ,  $MSE=.0017$ ,  $p<.02$ , and an analysis of the main effect of overall condition error between experiments was found,  $F(1, 22)=4.66$ ,  $MSE=.011$ ,  $p<.04$ , with performance under the temporal condition higher than that under spatial and item conditions, and spatial condition performance lowest overall.

### Discussion

The two portions of this experiment were designed to investigate further the coding strategies primary to each condition, visual, acoustic or perhaps another strategy not considered in previous experiments. The analysis of confusion error in each of the parts of this experiment revealed no reliance on either visual or phonetic coding. The introduction of acoustic suppression and the resultant (and unexpected) increase in retention accuracy does provide insight concerning the strategy employed when suppression is introduced. Feedback from each subject upon completion of all three

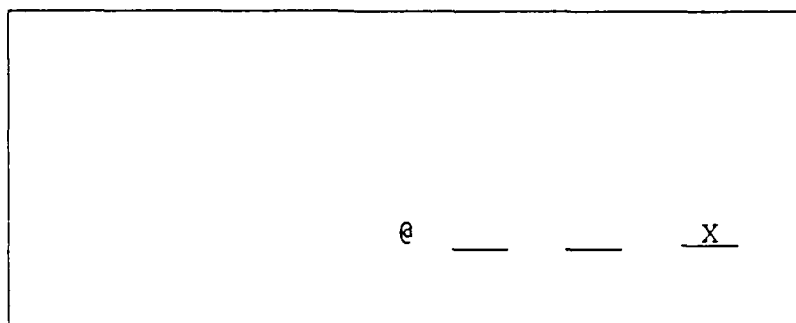
blocks of trials revealed that a spatial coding strategy was quickly learned by most subjects, and effectively used under all conditions. This strategy involves an ordering of the correct response according to the plane or trajectory in which the targets appeared. One of the constraints of this experiment required that responses must be entered in a specific order according to the type of information to which the subject was attending. Under the temporal condition, responses were entered according to the order in which the targets appeared. As there were only three planes in which targets appeared (left, middle and right), the subjects using a spatial coding strategy noted in which planes the first and second targets appeared. Identification of targets by the letters F, P and V was not necessary using this strategy, as the response is now based on which plane appeared first and second. The keyboard configuration in this experiment, as in the previous experiments, was modified so that the three keys used in responding represented each of the planes in which the targets appear. When, for example, during the temporal condition the middle target appeared first, the right target second, and the left target last, the subject coded the first target (in this case the middle) as a "starting" position, and the second target as a direction, either clockwise or

counterclockwise (in this case clockwise), in which the response would be entered on the keyboard. This strategy may be effectively applied to any of the experiments conducted in this study, as the display always consisted of this three-trajectory presentation. When the word "red" was required to be vocalized as the target appeared, this strategy was reported by all twelve subjects participating in the portion of this experiment which included acoustic suppression, but this was not the case when target letters were read aloud by the subjects in the second portion of this experiment. Though it is difficult to determine which of the subjects may have used a spatial coding strategy, the availability of phonetic coding seems to account for a higher degree of retention loss when the targets are identified as they appear. This is not reflected in the analysis of confusion errors when comparing the phonetic error (P/V transpositions) to the other types of possible error, and perhaps indicates that phonetic confusion between targets is not of the same nature as the interference attributable to vocalizing targets as they appear.

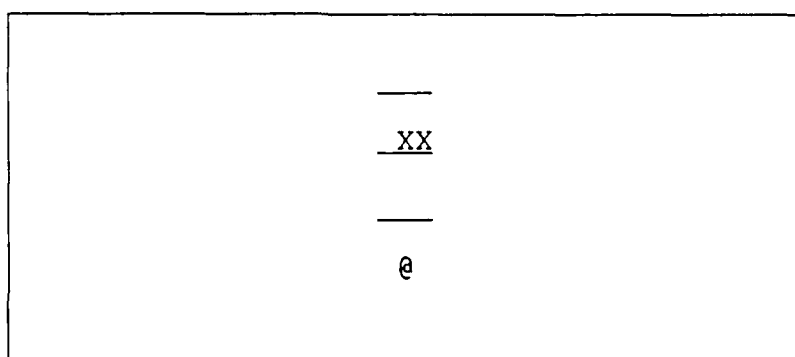
## CHAPTER 5

### EXPERIMENT 4

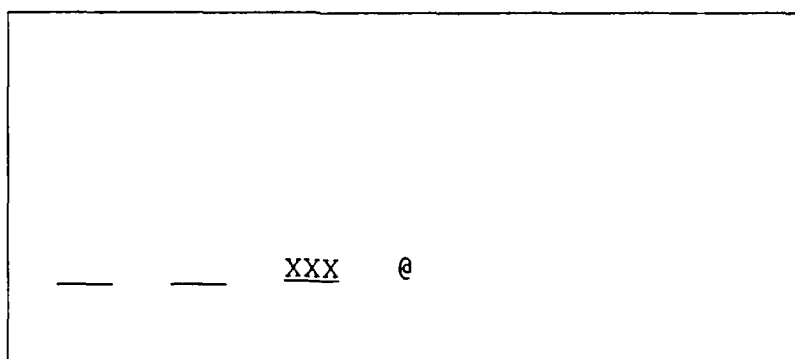
Experiment 4 introduces visually confusable targets which should require the use of a strategy which is neither visual nor acoustic in nature. This entails the use of targets which are presented as in Experiment 3, replacing the letters "F", "P" and "V" with the letter "X". Examples of each condition may be found in Figures 5.1, 5.2 and 5.3. The purpose of this design is to determine if the subject reverts to the use of a single coding strategy under all conditions. The temporal condition may still result in a higher degree of recall, because the order of items equals the order of response, but recall proportions are expected to be similar between spatial and item conditions, where targets must be transformed to a correct response ordering before a response is entered on the keyboard. The same distractor paradigm used in the third experiment is used in this experiment with the exception of two additional retention intervals, a "zero" interval where no intervening digits are displayed so that differences in encoding times may be determined, and a 36-digit interval intended to investigate further accuracy loss over time.



Frame 1



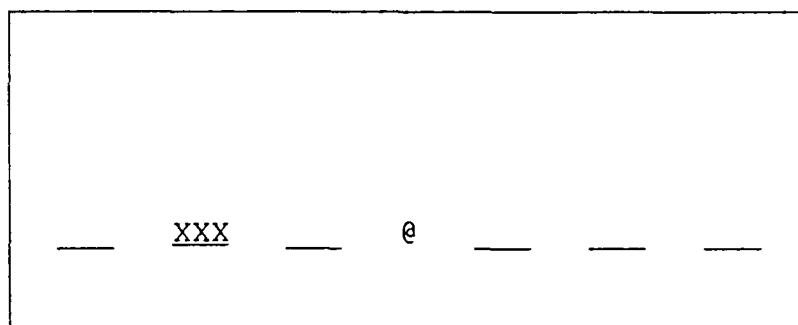
Frame 2



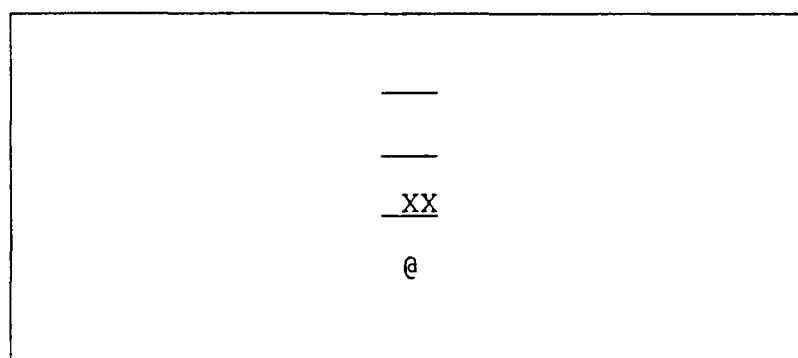
Frame 3

Figure 5.1

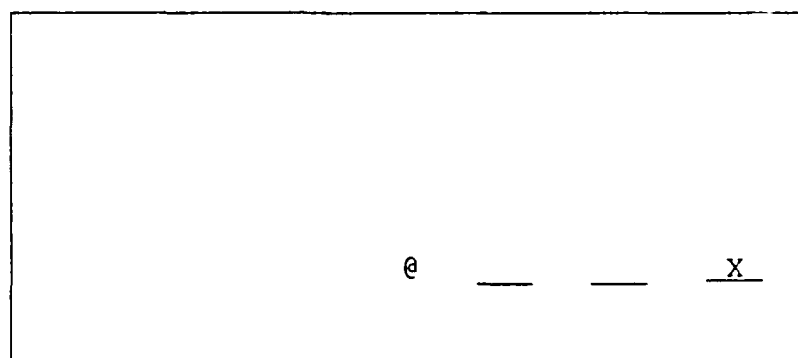
Sample presentation of a temporal condition trial  
 as frames appear on the computer screen  
 during Experiment 4B. Correct response  
 is right, middle, left



Frame 1



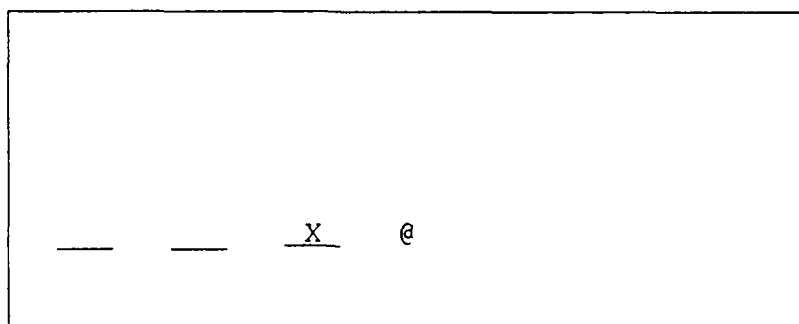
Frame 2



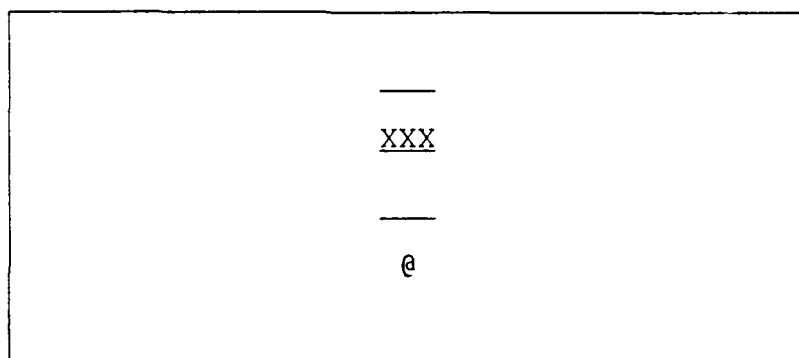
Frame 3

Figure 5.2

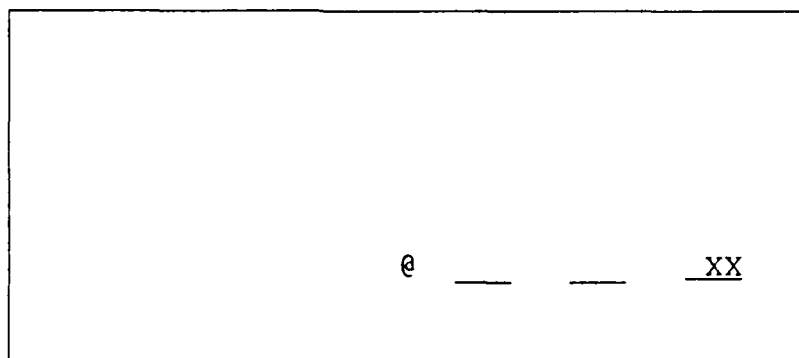
Sample presentation of a spatial condition trial  
 as frames appear on the computer screen  
 during Experiment 4B. Correct response  
 is middle, left, right



Frame 1



Frame 2



Frame 3

Figure 5.3

Sample presentation of an item condition trial  
as frames appear on the computer screen  
during Experiment 4B. Correct response  
is middle, right, left

As in the third experiment, subjects were divided into two groups, with the first twelve subjects responding to the letters "F", "P", and "V", this group designated as part 4A, and the second group (4B) responding to the letter "X", which replaced one-for-one the letters used in the first portion of this experiment, thus providing a comparison which is intended to isolate the effects associated with target appearance.

#### Method

Subjects. Twenty-four new subjects were drawn from the Introductory Psychology subject pool. Sessions were conducted in the same manner as the previous experiments.

Apparatus and materials. The PDP 11/03 and VT100 again provide stimuli presentation. The first twelve subjects responded to the same visual stimuli found in the third experiment, with the exception of the two additional retention intervals. Each of the four retention intervals contains as the correct response all six permutations of the possible response set, and Distractor digits appear as in previous experiments. This design is then modified through a global change in the stimuli, where the letters "F", "P" and "V" are replaced with the letter "X", the number of X's equalling

the number of letters appearing in that position (e.g. "FFF" appears as "XXX", "PP" as "XX" and "V" as "X"). The sequence of target presentations and variation of retention intervals duplicates the presentation of targets in the first half of this experiment. The same procedure for randomization of condition order is also employed. The subject's responses are recorded when entered on the modified computer keyboard as in the previous experiments, according to the plane (left, middle or right) in which the stimulus occurred.

Design and procedure. The testing sessions in the present experiment were conducted as in the previous experiments, with subjects tested individually in three blocks, each block devoted to one recall condition.

The categories of error possible in the first half of this experiment are the same as in the previous experiment where the letters FPV are used. This is not the case when all letters are replaced with the letter "X". In this instance, acoustic errors should be prevented through the use of targets which are similar in appearance, and where only size differentiates target identification. Digits appear in three's (e.g. "444"), as in the previous experiments of this study, and are of the set 444, 666 and 888, but are read as if only a single digit due to the short duration between digit

presentations.

Data scoring. Responses were recorded by the computer as the subject entered them on the keyboard. Data are analyzed for response error according to the serial position in which the error occurred, and the analysis is further divided according to the retention interval for each trial. As in the previous experiments, a confusion error analysis was conducted on the first portion of this experiment where the letters FPV appeared, to determine if any single confusion error type could be the cause of a higher degree of retention loss under each of the conditions and retention intervals.

### Results

The addition of a zero-retention interval, where no intervening digits were displayed, was expected to result in a ceiling effect, indicating that no loss in response accuracy occurs when a set of distractor digits is withheld. Conversely, the addition of a long (36 digit) retention interval was expected to produce a response accuracy loss higher than that at the 12-digit interval, and would perhaps indicate a monotonically increasing effect of loss over time. Data were analyzed for the proportion of correct responses by retention interval, with the results of each portion of this

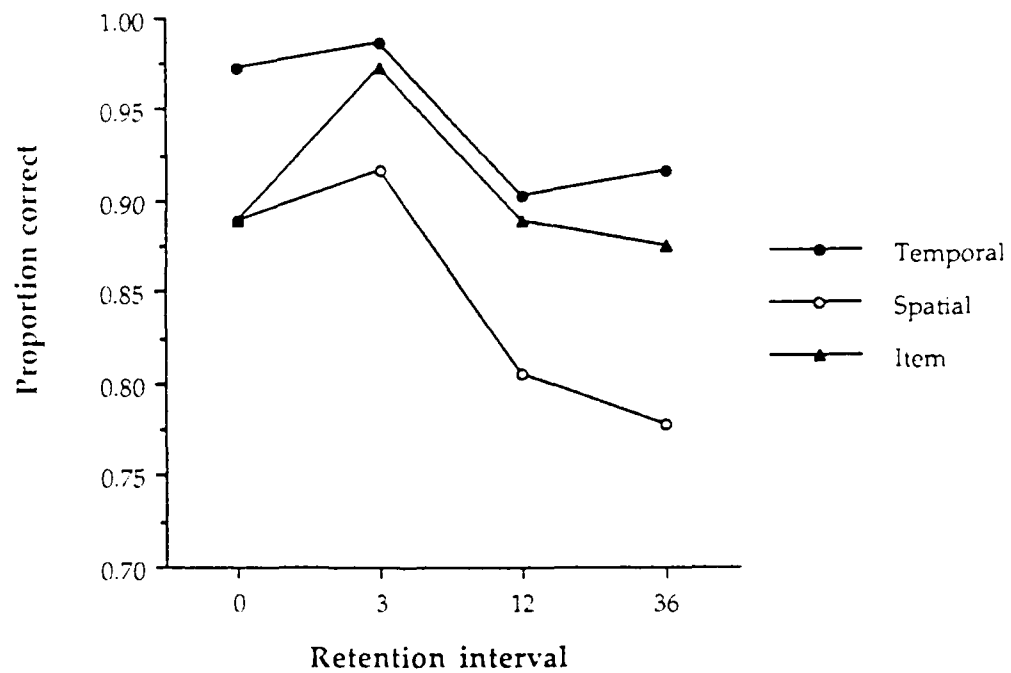


Figure 5.4

Proportion correct in the temporal, spatial and item conditions by retention interval, Experiment 4A.

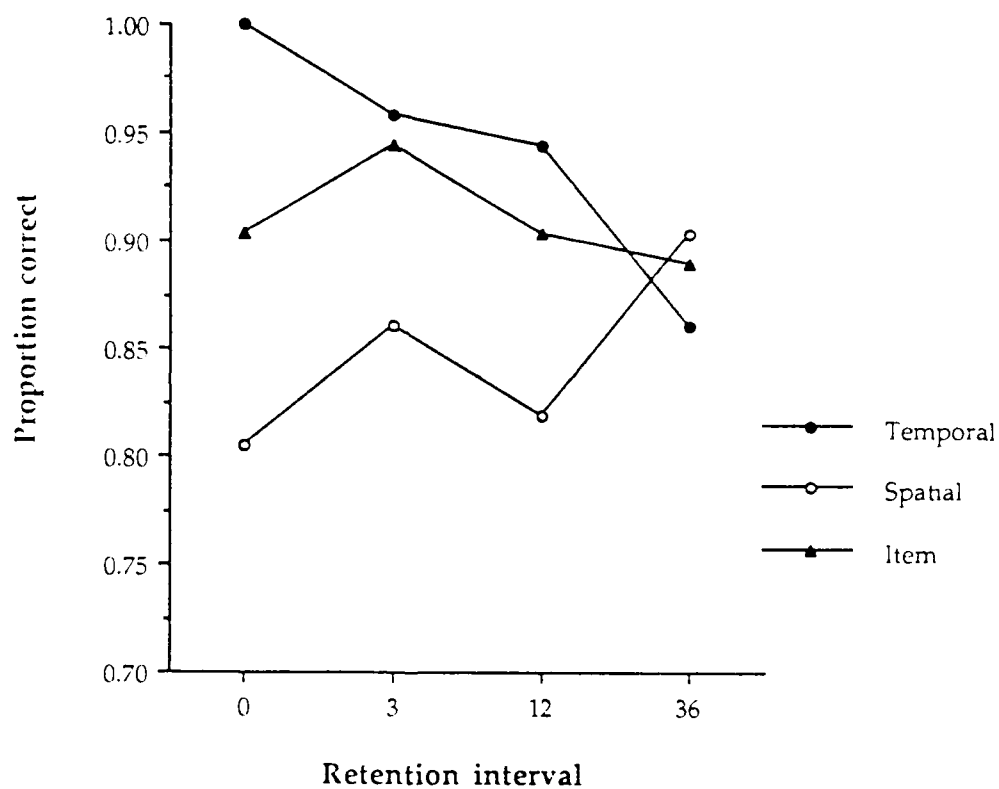


Figure 5.5

Proportion correct in the temporal, spatial and item conditions by retention interval, Experiment 4B.

experiment shown in Figures 5.4 and 5.5.

Surprising results are found in both of these experiments in that recall during the zero digit retention interval is lower than that found in the 12 digit retention interval during the spatial and item conditions.

An analysis of proportion correct by retention interval for Experiment 4A shows a significant difference between conditions,  $F(2, 22)=3.78$ ,  $MSE=.031$   $p<.038$ , with the temporal condition retention highest, as in the previous experiments included in this study, and a main effect of retention interval,  $F(3, 33)=5.11$ ,  $MSE=.016$ ,  $p<.006$ .

Item information recall in Experiment 4A (and 4B as well) is very close to performance under the temporal conditions, with the exception of the zero retention interval where recall rates were on the average about 8 percent lower. Spatial information was lowest in these two experiments with the exception of the 36-digit retention interval of experiment 4B, where performance between all three conditions was nearly identical. Although a significant difference exists between conditions in Experiment 4B,  $F(2, 22)=5.93$ ,  $MSE=.019$ ,  $p<.009$ , an analysis of retention interval differences was not significant, though an interaction of condition and

retention interval was found  $F(6, 66)=2.39$ ,  $MSE=.013$ ,  $p<.038$ .

A significant difference exists between 4A and 4B conditions,  $F(2, 44)=9.17$ ,  $MSE=.025$ ,  $p<.003$ , with performance during the spatial condition of 4B during the 0 and 3 digit retention intervals lower than in 4A, but nearly equal during the 12 digit interval, and much higher during the 36 digit interval. Additionally, performance during the item condition remained relatively flat, with no decrease in retention apparent as retention interval increases, and during the spatial condition of the second portion of this experiment, recall was highest at the longest retention interval. An overall difference in performance between retention intervals was found,  $F(3, 66)=5.44$ ,  $MSE=.014$ ,  $p<.003$ , but no interaction between condition and retention interval was found.

As in previous experiments of this study, a serial position analysis was conducted by condition and retention interval between experiments, and again a bow shaped curve was predominant, with the highest error occurring in position 2, with a significant main effect of position,  $F(2, 44)=8.73$ ,  $MSE=.0035$ ,  $p<.001$ . Serial position error results for Experiment 4A appear in Table 5.1, and for Experiment 4B Table 5.2. Significant main effects in experiment 4A were found for retention

Table 5.1

Proportion Correct in Each Recall Condition by Serial  
Position, Experiment 4A

		<u>Position</u>		
		1	2	3
<u>Condition</u>	<u>Retention Interval</u>			
Temporal				
	0	.958	.931	.917
	3	.972	.986	.972
	12	.958	.944	.931
	36	.917	.875	.889
Spatial				
	0	.958	.903	.944
	3	.931	.917	.931
	12	.861	.833	.861
	36	.861	.806	.861
Item				
	0	.917	.903	.931
	3	.986	.986	.986
	12	.944	.903	.917
	36	.917	.903	.972

Table 5.2

Proportion Correct in Each Recall Condition by Serial  
Position, Experiment 4B

		<u>Position</u>		
		1	2	3
<u>Condition</u>				
	<u>Retention Interval</u>			
Temporal				
	0	1.00	1.00	1.00
	3	.958	.972	.972
	12	.958	.958	.972
	36	.944	.903	.944
Spatial				
	0	.931	.861	.917
	3	.931	.889	.889
	12	.931	.861	.861
	36	.931	.903	.931
Item				
	0	.917	.958	.917
	3	.972	.972	.972
	12	.944	.958	.917
	36	.931	.903	.917

interval,  $F(3, 33)=3.53$ ,  $MSE=.0310$ ,  $p<.025$ , and position,  $F(2, 22)=6.39$ ,  $MSE=.0035$ ,  $p<.007$ . A marginally significant interaction between condition and position also exists,  $F(6, 66)=2.39$ ,  $MSE=.0027$ ,  $p=.0636$ . Serial position analyses of Experiment 4B show a significant interaction between condition and position,  $F(4, 44)=4.39$ ,  $MSE=.0032$ ,  $p<.0048$ , but no significant main effects of condition or retention interval.

An analysis of confusion error in part 4A of this experiment, where the target letters are FPV, resulted in a main effect of type of error, and a significant difference in performance between retention intervals,  $F(3, 33)=6.07$ ,  $MSE=.0033$ ,  $p<.003$ , but no significant interaction exists between conditions by retention interval and type of confusion error. Though visual confusion of targets was expected to be higher in part 4A of this experiment, visual and total transposition errors were equal, and significantly higher than acoustic and control errors,  $F(3, 33)=3.82$ ,  $MSE=.0044$ ,  $p>.019$ . Results are shown in Table 5.3.

### Discussion

As subjects were run individually, one observation noted by the experimenter was that subjects seemed to be surprised when no distractor digits appeared under the zero retention interval, even though they were

Table 5.3

Proportion of Errors that Reflect Letter Set  
Transpositions in Experiment 4A by Condition, Retention  
Interval, and Letter Set.

Condition	<u>Number of intervening digits</u>				
	0	3	12	36	Average
Temporal					
Control	.000	.014	.014	.056	.028
Acoustically confusable	.000	.000	.014	.000	.003
Visually confusable	.028	.000	.042	.042	.021
Compound error	.028	.014	.028	.042	.028
Spatial					
Control	.042	.000	.056	.028	.052
Acoustically confusable	.000	.028	.028	.028	.021
Visually confusable	.056	.000	.083	.069	.031
Compound error	.000	.056	.042	.069	.042
Item (size)					
Control	.000	.000	.000	.028	.024
Acoustically confusable	.028	.000	.014	.014	.014
Visually confusable	.014	.000	.042	.042	.007
<u>Compound error</u>	<u>.055</u>	<u>.014</u>	<u>.042</u>	<u>.014</u>	<u>.031</u>

prebriefed that this would occur periodically during the experiment. When trials other than the zero retention interval occurred, a common error noted among subjects was the misreading of a digit as the first few digits appeared during the retention interval. An explanation of retention loss during the zero interval may be tempered by the observation of these two behaviors, which seems to indicate that coding of target information is in effect even as the distractor digits begin to appear 500 ms after the last target appears on the monitor. When the task of reading distractor digits is expected, but when no digits appear, the subject might fall back on a phonetic or visual coding strategy which is somewhat less effective than the spatial coding strategy subjects used during experiment 3A of this study. This may also indicate a difference in processing time between conditions. Temporal information may be processed during the period of time that the targets are appearing, since the appearance of the first two targets facilitates immediate coding of the response. Spatial and item information processing requires a recoding of information into a response form because of the constraint imposed requiring a specific response order on the keyboard according to the type of information being coded. This

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processing requires more time than the coding of temporal responses, and the result is a higher retention rate during the short retention intervals of the temporal condition, which was found in all of the experiments conducted in this study.

## CHAPTER VI

### GENERAL DISCUSSION

This study was undertaken to determine if differences between primary coding strategies exist according to the recall condition under investigation. This study follows earlier work by Healy (1974, 1975b, 1977, 1978), and particularly the design found in Healy et al. (in press), but introduces additional constraints which are intended to show the extent to which phonetic and visual coding processes are used.

The presentation of targets on a computer monitor during this study is unique in that three distinct trajectories or planes are used rather than the use of a single Binaview cell as in Estes (1969, 1972, 1982) and Healy (1974), or the four different binaview cells and four horizontally situated spatial locations in subsequent Healy studies (e.g. 1975b). In addition to this configuration, a specific target letter is assigned to each of the three planes and used throughout the experiment, rather than targets drawn from a consonant set. The target letters were manipulated during one condition while holding constant the remaining two conditions investigated in this study. Subjects were

limited to a response order dependent upon the condition under investigation, where temporal information was reported in an order of first to last target appearance, spatial information was reported according to target distance from a given point, closest to farthest, and item information was reported according to target size or magnitude, from largest to smallest. Serial position analyses reveal the largest occurrence of error was in the second position in virtually all conditions and retention intervals, and because of the imposed constraint of reporting a specific order, it is reasonable to assume that primacy and recency effects were a factor in nearly every condition and retention interval.

Confusion error analysis was generally inconclusive in this study, providing no indication that a single type of confusion error, visual or phonetic, was attributable to a particular condition. Phonetic coding during the temporal condition was a common strategy reported by subjects during post experiment protocols, and is further evidenced by the significant retention loss as retention interval increases, and no loss in retention over time occurred when acoustic suppression was introduced in the third experiment. Through this experiment, a spatial coding strategy became apparent

when a near ceiling effect was obtained. Though this strategy is one which may be applied with equal effectiveness in any of the experiments conducted in this study, many subjects did not adopt this strategy, but rather relied on other less effective coding strategies. Subjects who discovered and applied a spatial coding strategy early during practice trials generally performed with little or no error, where subjects who never developed this strategy generally demonstrated an overall higher loss of retention. Interestingly, this strategy is essentially forced on the subject, and quickly recognized, when acoustic suppression is introduced and phonetic coding strategies disrupted. This is not the case when visual coding interference is introduced as in Experiment 4B, where target distinction is difficult. Under these conditions, performance is not significantly better (nor worse) than when visually distinguishable targets are used (distinct letters as opposed to X's appearing in all positions). Though a spatial coding strategy was available, it was not as readily adopted as in Experiment 3A.

It is important to note that even when subjects reported the use of a spatial coding scheme, specifically the coding of an answer based on the plane in which it appeared, errors still occurred, and regardless of the

strategy employed, overall performance during the spatial condition trials was generally lower than that under temporal and item conditions. This is best exemplified during Experiment 3A, where spatial coding strategies were reported by every subject, yet a ceiling effect is apparent only under the temporal and item conditions, though the analysis of proportion correct by condition does not yield a significant difference in means, the retention of spatial condition information obtained in this experiment, as in every experiment in this study, is lower during both short and long retention intervals.

An indication of why means are lower during the spatial condition became apparent during the fourth experiment, when two additional retention intervals were introduced. A zero digit retention interval was added to confirm our expectations that with no delay retention would be perfect, or at least nearly so. The findings were quite contrary, with performance during conditions other than temporal only at a 90 percent recall level, and only 80 percent in Experiment 4B during the spatial condition. The task of processing stimuli into a coded response requires more time during the spatial condition than temporal, and to an extent during the item condition. This is demonstrated in two ways, first, by the high proportion of recall during the short retention

intervals of the temporal condition, where response coding begins with the first target and can feasibly end with the appearance of the second target, since the response corresponds with the order of target appearance and requires no reorganization before coding the answer. During the spatial and item conditions, two targets must appear before the subject can begin coding the response according to spatial location or item magnitude, and this processing time runs beyond the beginning of the retention interval where distractor digits were read aloud. A second indication of the amount of time required to code spatial information is reflected in Experiment 4, where the zero retention interval recall levels were low during the spatial and item conditions, and performance was actually better during the three-digit interval. With coding processes still in effect during the three digit-interval, we would expect some interference when digits appear, but a higher loss occurs when no digits appear. It seems that the anticipation of digit appearance and the subsequent realization that no digits will appear (and a response must immediately be entered) is a greater distraction than the actual reading of digits aloud.

In the beginning of this study, a question existed concerning how item information (magnitude of

stimulus in this study) compares to temporal order and spatial location. When nonconfusable targets as used in the first experiment comprised the stimuli, item information recall was nearly identical to temporal recall. This was true of the remaining experiments, with the exception of the second experiment, where a slight decrease in recall during the short retention interval occurred, and a leveling of loss over retention interval increase was also noted.

A final qualifier must be added before concluding this study. Because of the configuration of the stimuli presented on the computer monitor, certain aspects of these experiments do not directly map onto the recent temporal, spatial, and item information studies, such as the one by Healy et al. (in press). Although similar in nature, the task required during spatial location recall conditions and item magnitude conditions are unique to this study because of the presentation design, which confounds the coding process by requiring a reorganization of the information into a response order. A primary difference in results between these studies may be found in serial position error, and we believe that this difference is attributable to constraining the response in this study to a specific order so that computer scoring could be facilitated. The item

magnitude condition is also unique to this study, with size as a discriminating feature over selection of targets from a consonant set as in previous studies. Finally, the emergence of a spatial coding scheme during acoustic suppression may again be attributable to the method employed in presenting targets assigned to a specific quadrant or plane on the computer monitor. Presenting three targets in three distinct planes resulted (inadvertently) in the availability of a simple, effective spatial coding strategy, a strategy which subjects inevitably reverted to when acoustic suppression was introduced into the trials, a finding not unlike that of temporal-spatial pattern coding described in Healy (1975b).

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